



The Potential Role of High-temperature Stationary Fuel Cells in the Development of an Early Hydrogen Infrastructure

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Why should a facility consider a stationary Fuel Cell?

- ⌘ Efficient electrical production
 - Load leveling and peak shaving
 - Meeting increased facility electrical demand
 - Distributed power generation vs. centralized power distribution
 - Increased electrical efficiency vs. centralized power distribution
 - elimination of transport and distribution losses
- ⌘ Facility mission (state, government and other research facilities)
- ⌘ Grid interruptions: backup/failsafe power
- ⌘ Availability of financial incentives for early introduction of stationary FC power
- ⌘ Early hydrogen vehicle fueling infrastructure
 - Hydrogen internal-combustion-engine vehicles
 - Hydrogen fuel cell vehicles

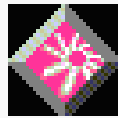


What are some of the “downsides”?

- ⌘ Initial cost
- ⌘ Uncertain reliability
 - “Bleeding edge” technology
- ⌘ Integration into existing facility and electrical power systems



How does a fuel cell work?



Fuel Cell Demonstration
(Macromedia “Flash” Animation)



Fuel cell types

Low temperature

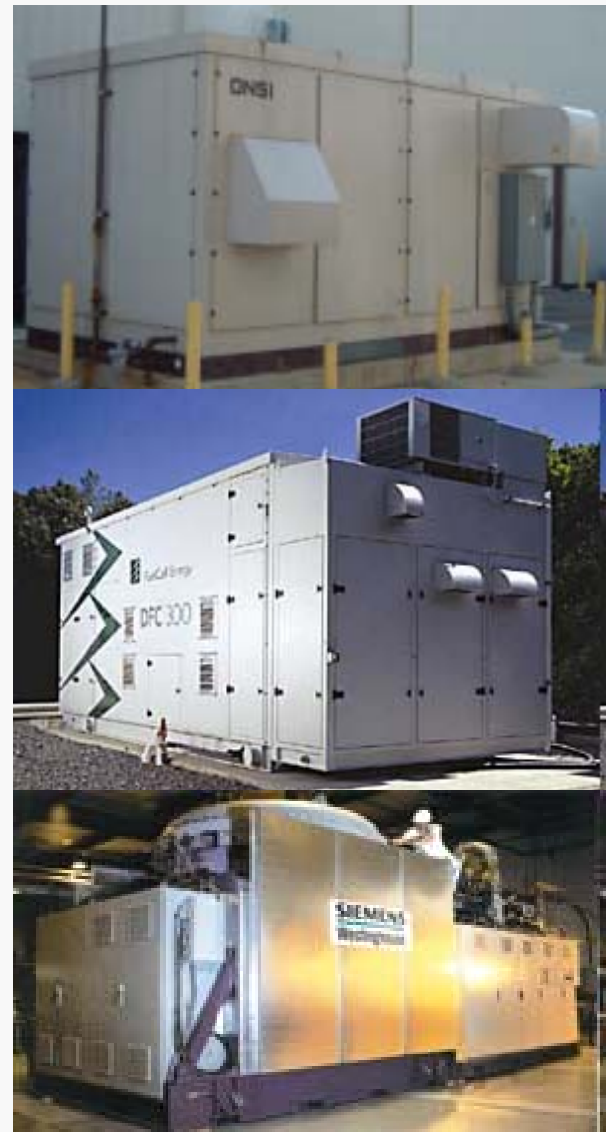
- ▮ Polymer electrolyte membrane (PEM-FC)
 - High power density
 - 85 °C operating temperature
 - Shows promise for mass-producibility
 - Examples
 - Automotive, APU, and Stationary fuel cells (Ballard, UTC, GM, Hydrogenics, Plug-Power)



Fuel cell types

High temperature

- ≡ Phosphoric Acid (PAFC)
 - 200 °C operating temperature
 - Examples
 - UTC PC-25
- ≡ Molten Carbonate (MCFC)
 - 650 °C operating temperature
 - Examples
 - FCE DCF-300, DCF-1500
- ≡ Solid Oxide (SOFC)
 - 650 °C operating temperature
 - Examples
 - Siemens-Westinghouse
 - Delphi



Why high-temperature stationary fuel cells?

Electrical efficiency is currently lower than PEM (~40% vs. ~50%), so why choose a higher temperature FC over PEM?

≡ Availability of high quality “waste” heat

- Increased efficiency of fuel processing into hydrogen
 - Generation of process heat needed for fuel reforming
 - Generation of high temperature steam for fuel reforming and CO cleanup (MCFC, SOFC)
- Co-generation can boost efficiency to over 85%
 - Building hot water (PAFC)
 - Building steam (MCFC, SOFC)

≡ Durability

- Some units have demonstrated >40,000 hour fuel cell stack durability (PAFC, MCFC)
- PEM-FC stack durability is still in ~2,000-4,000 hours
- Much higher tolerance of fuel contaminants than PEM-FC (sulfur compounds, CO)
 - Especially true of emerging SOFC technology



Experience with UTC PC-25 200 kW PAFC at U.S. EPA-NVFEL in Ann Arbor, MI

First 36 months

- ⌘ Intermittent problems due to early “prototype” hardware
 - Stack problems
 - Cooling system problems

Previous 6 months

- ⌘ Reliable 24/7 operation, ~150 kW average continuous load
- ⌘ Net facility savings:
 - ~\$13,500/year electricity
 - ~\$16,000/year hot water heat
 - Current natural gas contract price: \$4.70/million-SCF
 - If operated in a 8.5 hour/day peak shaving configuration:
 - Electric savings ~double
 - hot water savings ~halve

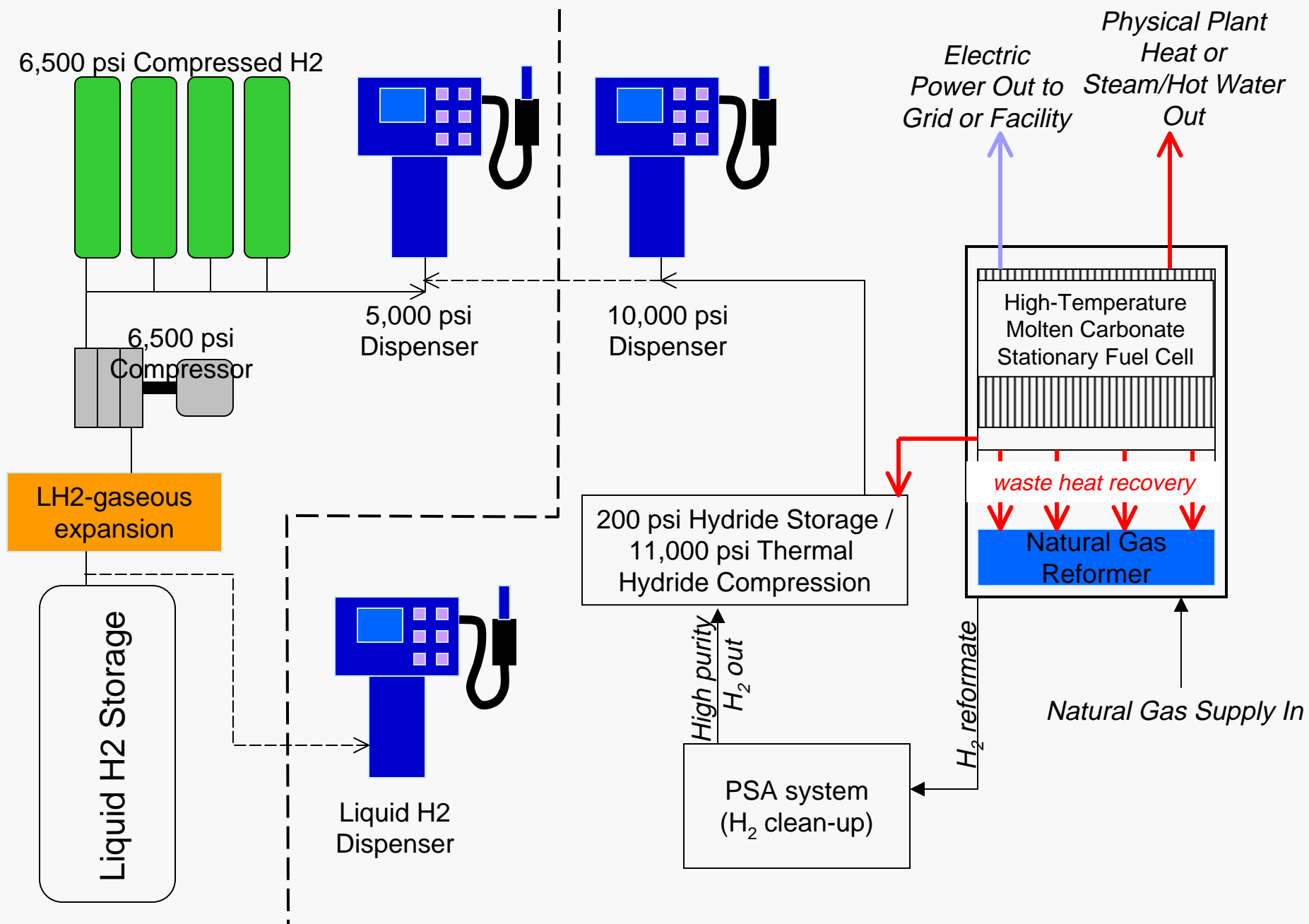


So what does this have to do with fuel cell vehicles and H₂ infrastructure?

- ⌘ Steam reformed natural gas is the primary source of H₂ for refineries and other uses in the U.S.
 - An early hydrogen infrastructure for fuel cell vehicle introduction into centrally fueled fleets can potentially rely on distributed fuel production from natural gas
 - Reformers work best under a relatively constant load – start-up and shut-down should be avoided
- ⌘ Currently available PAFC and MCFC stationary fuel cells have highly-integrated, efficient steam-reforming of natural gas to hydrogen
 - One 200 kW PAFC or MCFC fuel cell produces enough hydrogen from natural gas in a 24-hour period to completely fill 30 fuel cell vehicles
 - Clean-up of hydrogen reformate is needed to provide hydrogen of sufficient purity for PEM-FC vehicles



Concept: "Hydrogen Energy Park" with H₂ Vehicle Filling Station



High temperature fuel cells as a source of H₂ vehicle fuel

- ≡ Stationary fuel cells provide a built-in hydrogen “sink” to prevent over-production of hydrogen vehicle fuel
 - Electrical generation can be increased when the demand for vehicle fuel is low
 - Hydrogen can be produced and stored primarily during “off-peak” periods of electrical usage
 - Stored hydrogen can be use either as vehicle fuel, or can be used to fuel the stationary fuel cell during periods of “peak” electrical usage
 - A 200 kW PAFC operated at ~150 kW continuously can still provide sufficient H₂ to fuel 2-urban buses or a small light-duty vehicle fleet (4-8 vehicles depending on usage)
- ≡ MCFC tail-gas is hydrogen-rich (~ 25% H₂), allowing production of vehicle fuel even when a full electrical load is applied to the stationary fuel cell
- ≡ Process heat from MCFC’s can be used to provide compression to high pressures using thermal hydride compression

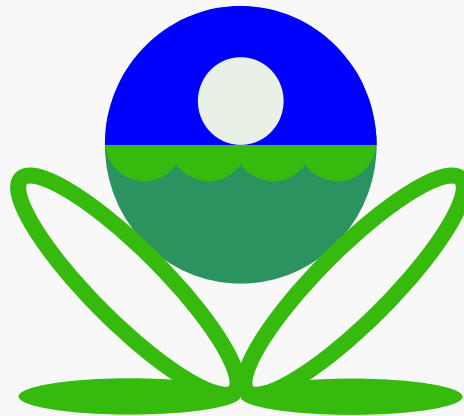


Summary

- ⌘ High temperature stationary fuel cells can make sense for meeting facility electrical and heating needs
- ⌘ Each stationary fuel cell has the potential to produce hydrogen for fuel cell vehicles as part of an emerging distributed hydrogen production and distributed electrical generation system



For more information:
<http://www.epa.gov/fuelcell>



Thank you